

The dry-hot valleys and forestation in southwest china

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Abstract: The dry-hot valleys (DHV) are located mainly in the deeply incised valleys along the upper streams of several international and domestically rivers, like Yangtz, Zhu, Lanchang, Hong, and Nu rivers. This paper briefly described the reasons of formation of DHV from view of climate and geographical conditions, and by referring to great deal of documents, analyzed the historical case and present status of the vegetations in DHV. The environment in DHV is facing the serious vulnerable period in the history due to its nature situation of half-year dry period, fragile geological structure and shallow soil, and its social situation of over dense population and over farming. The primary vegetation is broad leaf forest and it was denuded in the history. The current local vegetation is the degraded secondary vegetation: savanna and succulent thorny shrub. Since the environmental situation in valley influenced directly the water body of river, the soil erosion control and re-vegetation in DHV is the most urgent task in the process of environmental harness along the rivers. Quite a few pilot research projects have been carried out on demonstrating new silviculture techniques for re-vegetation in DHV, but there still exist great difficulties in carrying out large-scale afforestation engineering.

Key words: Dry-hot valley; Forestation; Environmental harness

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Introduction

The concept of the dry-hot valley (DHV) is derived from the so-called "dry basin" in Yunnan Province. Such valleys are located mainly in the deeply incised valleys along the Nu River (upper reach of Salween), Lanchang River (upper reach of Mekong), and Upper stream of Yangtz River; including its tributaries the Yalong, Dadu, Min, Yuan, and Baishui rivers in Hengduan mountainous area (Zhang 1992). The northern limit of the dry-hot valleys is the Baishui River valley along the headwaters of the Bailong River at latitude 23° N. The southern limit is the Yuan River valley, particularly the headwaters of the Hong River at latitude 22° 33' N. To the east the boundary includes the lower reaches of the Jinsha River and the Dadu River, and to the west the counties of Changdu and Basu which are eastern Tibet (Sichuan Vegetation Cooperation Group 1980, Yunnan Vegetation Composition Group 1987).

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The existence of dry-hot valleys (DHV) was confirmed by a comprehensive survey of Hengduan mountainous region. This survey was part of a larger study of the Qing-Zang Plateau that took four years (1981-1984) and was undertaken by members of the Chinese Academy of Sciences. Based on their climate, these dry valleys can be divided into 3 types: dry-hot, dry-warm, and dry-temperate (Zhang 1992). The mean temperature of the coldest month in the *dry-hot* valleys is over 12 °C, while the mean temperature of the warmest month is between 24-28°C. Each year 350 d have temperatures greater than 10°C. The temperature regimes of the other two climate-type valleys are lower than that of *dry-hot*.

The total length of the dry valleys in Hengduan mountainous area is 4 105 km, with an area of 11 230 km². The most significant area for the development of these dry valleys is in the headwaters of the Yangtz River: such as the Jinsha (including its tributaries the Yalong River and Dadu River), Min, and Bailong rivers. For example, the area of the dry valley along the Jinsha River comprises more than half of the total area of dry valleys extending for 2 929 km, having an area of 8 410 km², which accounts for 71.4% and 74.9% respectively of the total length and total area of dry valleys in the Hengduan mountainous area. In this region, the dry-hot valleys alone have a total length of 1 123 km and an area of 4 840 km² (Zhang 1992, Chinese Vegetation Composition Committee 1983).

Because of their significant length and area the research and investigation of the dry-hot valley along the Jinsa River have relevance to the entire ecological recovery of the Yangtze River valley. The following discussion therefore focuses mainly on the re-vegetation of the dry-hot valleys found along the Jinsa River.

The formation of the dry-hot valley

So far, few specific researches have been carried out on the climate of the dry-hot valleys and long-term data records are less. As a result, most discussions and analyses regarding the formation of the dry-hot valleys are hypothetical. The major factors identified as being relevant include: the atmospheric circulation system, the influence of the mountains and geographic position on the movement of the monsoon and in enhancing the foehn effect, the local wind current systems, but in particular the mountain-valley system; and human activities (Zhang 1992, Sichuan Vegetation Cooperation Group 1980).

Once air current from the Atlantic and India Oceans pass over the Qing-Zang Plateau they descend into the deeply incised valleys. This adiabatic airflow compresses the air leading to a rapid increase in temperature in the valley. In addition, localized heating and cooling over the Qing-Zang plateau causes a 'plateau monsoon' in this region. Heating and cooling lead to pressure differentials and causes wind around the plateau to converge in summer (hot low pressure) and diverge in winter (cool high pressure). This localized effect, while relatively thin and isolated, is still significant enough to disrupt the more regional circulation model.

The physical barrier formed by the Hengduan Mountains across the humid air stream also has a pronounced influence on the climate of the dry valleys. For example, when the air stream intersects the trend of the valley at a low angle the mountains have little influence and the air remains humid. However, when the valley intersects the southwest warm air stream at right angles the climate becomes dry and hot, as any moisture is lost as the air moves over the mountains. The typical dry valley in the upper reaches of the Jinsa, Lanchang and Nu rivers has therefore developed because the mountains prevent the entry of the humid air stream. In the deeply incised dry-hot valleys, where the relative relief exceeds 1500 m, the foehn effect caused by the rain shadow on the leeward slope enhances this effect and plays an important role in the formation of the dry valleys in this area.

Local circulation resulting from the mountain-valley wind system also plays an important role for the formation of the dry-hot valleys. During the day, air on the valley sides is heated more than that on the valley

floor. This results in a wind current as air in the bottom of the valley rises along the slope. At night, the situation is reversed with cold air on the upper slopes, sinking to the valley floor and causing a valley wind. Convergence of the rising cool and descending humid air currents results in the formation of clouds and a mist zone on the sides of the valley. This raises the temperature and decreases the humidity of the descending moist air enhancing dry conditions and drought in the bottom of the valley.

The effect of the destruction of the vegetation in the dry-hot valleys cannot be underestimated. Savanna and xerophilous deciduous shrub are now the dominant secondary vegetation, since forest removal (Sichuan Vegetation Cooperation Group 1980, Yunnan Vegetation Composition Group 1987). Within the dry-hot valley areas the ecological environment is particularly fragile. Once the natural vegetation cover is disturbed by human activities recovery is very difficult. This can further enhance the development of the drought in the valley.

Natural vegetation

The earliest description of the vegetation in the dry-hot valley is found in the *Diary on touring in Yunnan Province* written by Xu Xiake during the Ming Dynasty (Xu 1985). He arrived in the Yuanmou Basin on the 6th December 1638 AD. He described the Earth Forest (a place currently become a tourism site for the soil has been seriously eroded into column shape and looks like different trees standing) as follows: "*Bambax trees grow to more than 1 zhang and the leaves can last for 2 to 3 years. There is a dry ravine from the west with a precipice stretching along it, The sand at the base of the ravine is a foot-deep. There is no water in the bottom of the ravine. The soil was eroded into column shape in different size and looks like a ghost in the moon night. The sand is white, which is not likely to be salt but frost from the ground.....*" This description suggests that the vegetation at that time was not too dissimilar to the savanna landscape of today.

Western scientists have investigated the botany and collected specimens, in the Jinsa River area on a number of occasions since the 19th century (Chinese Vegetation Composition Committee 1983). Chinese scientists, however, began systematic botanical investigations in this area after the 1930s. Their findings are to be found in a series of works such as '*Chinese vegetation*' (Chinese Vegetation Composition Committee 1983), '*Yunnan vegetation*' (Yunnan Vegetation Composition Group 1987), '*Sichuan vegetation*' (Sichuan Vegetation Cooperation Group 1980), and '*Dry Valley in the Hengduan Mountainous Area*' (Zhang 1992). Although there are some differences in detail,

all these works class vegetation lower than 1400 m above sea level as "the vegetation of the dry-hot valley" (Sichuan Vegetation Cooperation Group 1980, Yunnan Vegetation Composition Group 1987, Chinese Vegetation Composition Committee 1983). The main vegetation types are savanna and succulent thorny shrub. The main tree species are *Bambax malabaricum*, *Oroxylon indicum*, *Quercus franchetii*, and *Franxinus malacophylla*, main shrubs are *Phyllanthus emblica*, *Dodonaea viscosa*, *Albizia kalkora*, and *Acacia farnesiana*, and the main herbs are *Heteropogon contortus* and *Cymbopogon distans*.

At present therefore the dry-hot valleys contain secondary vegetation that has been modified significantly by human activities. The original vegetation was most likely mixed forest consisting of broad-leaved deciduous and evergreen tree species. It is hoped that "natural" forest vegetation may be able to be re-established in the dry-hot valley using artificial means.

Ecological volubility

The ecological fragility of the dry-hot valleys is shown by a number of indicators, including: the dramatic deterioration of natural environment; increasing desertification; increasing vegetation destruction; decreasing biological diversity; and serious soil erosion (Zhao 1998). Ecological fragility is a result of both natural factors, such as low rainfall and thin soils, and the rapidly increasing population and intensification of landuse.

Low rainfall and high evapotranspiration rates are the principal characteristics in the dry-hot valleys (Zhang 1997). For example, the Yuanmou dry-hot valley has an average of 2 670.4 h of sunshine per year, a mean annual temperature of 21.9°C, and an annual accumulated temperature for >10°C days of 7 796.1°C. The ready availability of energy in the form of heat accelerates evaporation. The local meteorological department measured evaporation in the Yuanmou dry-hot valley using a small evaporating dish. It is estimated that the annual pan evaporation rates is up to 3 847.8 mm while the mean annual rainfall is only 634 mm (annual rainfall ranges from 287.4 mm to 906.7mm). On average there are 91 raining days per year, with 90% of the precipitation falling between June and October (the data from the meteorological bureau of Yuanmou County, 1949-1996). During the six-month dry season evaporation rates exceed rainfall by at least an order of magnitude and relative humidity is zero. Under such harsh climatic conditions plant growth is stressed with many species unable to survive, particularly young tree seedlings. Yuanmou County for example, had to cancel its involvement in the con-

struction of the shelter-forest network for Yangtz River because the survival rate of its afforestation program did not meet the national criterion. In addition, even 20-year old *Pinus Yunnanensis*, planted as part of an experimental afforestation project in Huangguayuan Town of Yuanmou County, died because of the extreme drought (personal communication with Wu Jukui 1999).

Most soils in the dry-hot valleys along the Jinsa River are developed from the purple sandstone and the sandy shale (Xu and Ma 1999). Soil development is, however, always rudimentary with the soils being thin and having poor water holding capacity. Increasing population pressures and intensification of land-use has also accelerated soil erosion and desertification. This reduces the carrying capacity of the soil even further and promotes continued environmental deterioration.

The ecological system is so fragile that once the vegetation cover is destroyed recovery is extremely difficult. Past vegetation destruction has reduced forest cover in the Jinsa River basin to be below 10%; in some counties it is below 6% and in the valley proper approximately zero (Ma 1999).

A good vegetation cover helps to prevent erosion through a number of mechanisms. First, the canopy intercepts a percentage of the rainfall so that it never reaches the ground. Additional moisture may be held within the litter layer. The root system helps to bind the soil particles and prevent them from being washed out and eroded by surface runoff. Vegetation also increases the organic content of the soil that aids in the development of aggregates, improves infiltration rates and permeability, and increases resistance against soil erosion (Wang 1995).

Once vegetation cover is destroyed the soil is easily eroded by surface runoff. Because of the thin nature and the low organic content of soils in the dry-hot valley area soil erosion is quite serious. Using remotely sensed data from satellite imagery taken in 1985 soil erosion in the upper reaches of the Yangtz River was estimated to affect up to 350 000 km². Approximately 1 600 million tons of soil is eroded every year (Cha and Li 1998).

The natural ecology and environment of this area has changed dramatically because of the destruction of the original vegetation cover. Species diversity has been decreased markedly. Many rare species (e.g., *Panzhihua* from the Delonix region of Sichuan Province) are now threatened because their habitat has been reduced and isolated, which is leading to cross-breeding. It is also very difficult to prevent and control plant diseases, and to eliminate pests, because of the development of a vegetation monoculture.

A project for ecological and vegetation recovery

As a result of the increasing environmental degradation in the Yangtz River basin, in 1989 the Chinese government started the "*Project for the construction of a shelter-forest network for the middle and upper reaches of the Yangtz River*" and the "*Project for water and soil conservation for the middle and upper reaches of the Yangtz River*" (Wu and Ma 1996). Several hundreds of million yuan were invested in re-vegetation and water and soil conservation. After more than ten years' work the hills in the Jinsa River catchment started to turn green because of the dramatic increase in forest vegetation. Soil erosion also decreased significantly. The German government then twice invested DEM 24 000 000, supported by a Chinese government 1:1 contribution, to aid the afforestation project in the Jinsa River basin. Following the catastrophic floods on the Yangtz River in 1998, the Chinese government placed even more importance on the environmental recovery in this area. They have committed a large amount of money to support two major initiatives "*The project of natural forest protection*" and "*The project for the ecological recovery of the middle and upper reaches of the Yangtz River*" (data from Yunnan Provincial Department of Forestry 1999). These large projects, involving an investment of billions of yuan, will be commenced in the near future. The harsh climate of the dry-hot valleys, however, mean that recovery technique successful elsewhere are untested and may not be effective.

Because of the numerous, and varied, linkages which operate in the natural environment successful re-vegetation is essential to sustainable management of the whole basin. The lack of success so far in re-vegetating the dry-hot valleys means that some of the most difficult work associated with the ecological recovery of the middle and upper reaches of the Yangtz River is still to be achieved.

To assist with forest recovery in the dry-hot valleys, the Yunnan Provincial Department of Forestry has undertaken a number of re-afforestation experiments in the Yuanmou valley since the 1970s. The former Minister of Forestry subsidized these experiments ("*Techniques for vegetation recovery in Jinsa River valley*") under the Eighth & Ninth Five-year Plans (Zhang 1997). The Yunnan Provincial government also subsidized this work via the "*Management models, afforestation technique and species selection for fuelwood in dry-hot valley and central plateau in Yunnan Province*" project (Wu 1996). As a result of these efforts some exotic tree species such as *Eucalyptus* spp. and *Acacia* spp. have been tested and planted successfully in the dry-hot valleys. A

series of advanced afforestation techniques suited to specific local situations, such as water supply catchments, are also now being applied widely.

Considerable research has also been undertaken on various water issues and the future stability of the "artificial" forest planted in the dry-hot valleys. Through nursery experiments and field observation it is now possible to predict the long-term stability of various species under different field conditions and planting densities (Ma 2000). This provides a theoretical and practical basis for large-scale afforestation to take place as part of the shelter-forest network for the Yangtz River.

At the same time as studying re-vegetation research was also undertaken on the sustainable exploitation and management of the dry-hot valleys. The Yunnan provincial government subsidized this work through the "*Research on the resource exploitation and management of the Dry-Hot Valley along the Jinsa River*" project. More than 20 counties were surveyed and investigated resulting in a research report of almost half a million words (Wu and Ma 1996). A team from the Chinese Academy of Sciences also studied the environment and agricultural landuse of the dry valleys in Hengduan mountainous area from 1981 to 1984. This culminated in a book titled "*Dry-valleys in the mountainous Hengduan area*" published by the Science Press (Zhang 1992). In addition, the Research Association for the Modernization of Agriculture in the National Region in Sichuan Province, the Forestry Association of Sichuan Province, and the Forestry Association of Aba Autonomous Prefecture held a "*Symposium on the synthetic management in the Dry Valleys*". A collection of papers presented at the symposium was subsequently published (Forestry Association of Sichuan Province 1993).

The research discussed above has laid the foundation for large-scale re-vegetation in the dry-hot valley. Through improved research, and the use of practical effective examples, it is hoped that large-scale re-vegetation can commence at the beginning of next century.

Suggestion

Re-vegetation of the dry-hot valleys will be a long-term project working outwards from the relatively easy, high profile, areas until the entire area is covered. Re-vegetation is closely linked to the interests of the local peasants and therefore attention must be paid to the participation and involvement of local communities. To be successful the project must combine the protective benefits to the environment with the economic benefits to the local people. A variety of multi-purpose species suitable to the environment must be found and used in an integrated

manner under the framework of agroforestry and the social forestry.

Development should also take the form of comprehensive management of relatively small watersheds, paying particular attention to the involvement and cooperation between different sectors, including the departments of agriculture, forestry, and hydraulics. Success of the project depends on highlighting the suitability and sustainability of the project.

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